Fresnel Coherent Diffractive Imaging from Periodic Samples

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In recent years the increased proliferation of high coherence X-ray sources such as third generation synchrotrons has helped in the advancement of new forms of microscopy. Among the techniques which are currently being developed, coherent diffractive imaging (CDI) is emerging as one of the most promising, offering the potential of very high resolution lensless imaging of non-crystallographic samples. Conventional experiments using CDI assume a perfectly coherent beam and utilize plane wave illumination of the sample. Recently it has been demonstrated that introducing curvature into the illumination can greatly assist in the recovery of a unique solution from the diffraction pattern.[1] A further interesting modification to the standard method for carrying out CDI is possible in the case of samples which are periodic.

Previous experiments using Fresnel CDI have relied on an iterative reconstruction of the exit surface wave (ESW) in which the entire illumination is reconstructed[2] and a support constraint applied to the amplitude. However, in experiments where the sample is known to have periodicity it is no longer necessary to reconstruct the entire object. Instead, an analysis of the sample can be carried out based upon only a single isolated unit cell. This scheme involves making an initial guess for the unit cell and replicating it to give a transfer function, which is multiplied by the incident illumination to give the ESW for the sample. The ESW is then propagated to the detector plane where consistency with the measured intensity is enforced. Finally, the ESW is propagated back to the sample plane where a single unit cell is isolated and the illumination is removed. The whole process is then repeated until convergence of the algorithm.

Studies utilizing simulated data have shown that this iterative phase retrieval scheme could, in principle, provide a significant enhancement in the reconstruction of periodic or even quasi-periodic objects compared to conventional CDI. Here we present experimental data from optical CDI measurements using curved beam illumination of periodic samples which test the effectiveness of this method of iterative image reconstruction. Among the issues we wish to address are the extent to which the method relies on the strict periodicity of the object, the quality of the reconstruction as a function of the number of unit cells which are 'well illuminated' in the sample plane and the effect of varying the curvature across a single unit cell compared to varying it across the entire object. We also outline a plan for extending these ideas to the X-ray regime and discuss possible applications of the technique, including a potential method for aiding in the recovery of information from biological samples.

(1) Williams, G. J.; Quiney, H. M.; Dhal, B. B.; Tran, C. Q.; Nugent, K. A.; Peele, A. G.; Paterson, D.; Jonge, M. D. d. *Physical Review Letters* **2006**, *97*, 025506.
(2) Quiney, H. M.; Peele, A. G.; Cai, Z.; Paterson, D.; Nugent, K. A. *Nature Physics* **2006**, *2*, 101.